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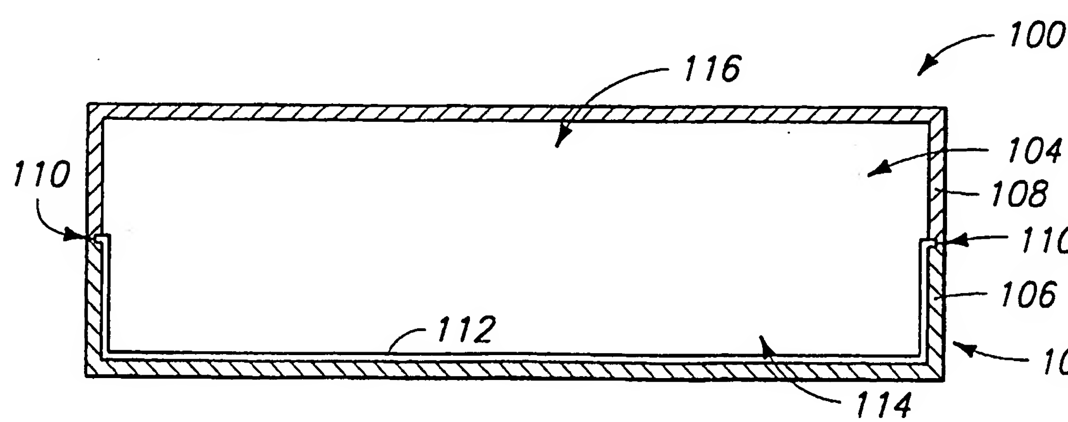

(57) **Abstract:** The invention includes a thermal transfer device. The device includes a housing which defines at least part of chamber sealed from the atmosphere, and a working fluid contained within the chamber. The housing can be formed of a composition which includes a polymer base matrix having a thermally conductive filler material dispersed therein. The housing can have a thermal

WO 03/017365 A2

Thermal Transfer Devices

TECHNICAL FIELD

[0001] The invention pertains to thermal transfer devices, including heat pipes and vapor chambers.

BACKGROUND OF THE INVENTION

[0002] An exemplary thermal transfer device is described with reference to Fig. 1. Specifically, Fig. 1 shows a construction 10 comprising a heat-generating component 12, cooling fins 14, and a thermal transfer device 16 for transferring thermal energy from component 12 to cooling fins 14. Component 12 can comprise, for example, a semiconductor construction, such as an integrated circuit chip. A problem encountered with integrated circuit chips, or with other heat-generating components, can occur if suitable cooling mechanisms are not provided proximate the components to allow dissipation of heat. For instance, if heat is not adequately dissipated from the components, thermal energy can build up within the components to a level which can destroy portions of the components, and eventually render the components inoperable.

[0003] Thermal transfer device 16 is provided to efficiently transfer heat from the heat-generating component 12 to cooling fins 14. Thermal transfer device 16 can comprise, for example, a vapor chamber. Device 16 can be provided in direct physical contact with component 12, or, as shown, can be spaced from component 12 by a thermally conductive interface material 18. Interface material 18 can comprise, for example, GELVET™ material, distributed by Honeywell International, Inc.

[0004] Cooling fins 14 are provided to radiate heat transferred from device 16, and accordingly to dissipate heat from component 12. Cooling fins 14 can be formed of various thermally conductive materials, such as, for example, metals or thermally conductive plastics, including plastics that are highly thermally conductive. Exemplary metals include copper and aluminum, and in particular applications the metals can

comprise alloys which include one or both of copper and aluminum. Cooling fins 14 join to device 16 at an interface 15.

[0005] Construction 10 is shown in cross-sectional view in Fig. 2 to illustrate operational aspects of thermal transfer device 16. Device 16 comprises a housing 20 surrounding a chamber 22. Chamber 22 is sealed from the atmosphere, and will generally have a pressure less than atmospheric pressure maintained therein. A wick 24 extends within chamber 22, and in the shown embodiment is provided along an internal surface of housing 20. Wick 24 can comprise, for example, a plurality of particulates bonded to housing 20 in a suitable manner. In a typical construction, housing 20 will comprise a thermally conductive metal, such as, for example, copper or copper alloys, and wick 24 will comprise thermally conductive metal particles (such as copper particles or sintered copper particles) adhered to housing 20 during the sintering process. Wick 24 comprises a roughened surface 26. Surface 26 is ultimately utilized to enable capillary flow of a fluid within chamber 22. Wick 24 can be replaced by other structures which enable capillary flow. For instance, wick 24 can be replaced by grooves and crevices formed within an internal surface of housing 20. Alternatively, wick 24 can be replaced by a screen or other mesh provided within chamber 22.

[0006] A fluid is provided within chamber 22, and is utilized to rapidly transfer thermal energy across thermal transfer device 16. The fluid is commonly referred to as a "working fluid" of the device. Device 16 comprises relatively warm regions 28 proximate component 12, and relatively cool regions 30 proximate cooling fins 14. The conditions within chamber 22 (specifically, the pressure within chamber 22 and the chemistry of the working fluid) are chosen such that the working fluid will vaporize from warm regions 28 and condense at cool regions 30. The vaporizing fluid is shown diagrammatically by arrows 32, and the condensing fluid is shown diagrammatically by arrows 34. Arrows 34 also show the fluid being wicked along surface 26 of wick 24 to be returned from the cooler portions 30 to the warmer portions 28 of transfer device 16. The vaporization of the fluid from warm portions 28 transfers heat from component 12 to

the fluid, and the condensation of the fluid at cool portions 30 transfers the heat from the fluid to the fins 14 from which the heat can be dissipated into an atmosphere surrounding fins 14. Numerous working fluids can be utilized in various thermal transfer devices, with a commonly-utilized fluid being water.

[0007] The technology described with reference to Fig. 2 can have numerous applications for efficiently cooling heat-generating components. For instance, heat-generating semiconductor devices are frequently incorporated into portable consumer goods, such as, for example, cell phones and laptop computers. It is frequently desired to provide a cooling mechanism for the heat-generating components, and yet to avoid the weight, bulk, and energy consumption associated with cooling fans. A thermal transfer construction of the type described with reference to Figs. 1 and 2 can be incorporated into such portable consumer goods, and can constitute an energy-efficient and relatively compact cooling mechanism. However, in utilizing cooling devices of the type described with reference to Figs. 1 and 2 in portable consumer goods, it would be desirable to reduce the weight and cost of such devices. Another application for cooling devices in which it is desired to reduce the weight and cost of the devices is space technology. Specifically, cooling devices are frequently utilized in satellite constructions, and it would be desired to develop new cooling devices which are relatively lightweight, and it would be further desired that such devices be relatively low cost.

[0008] Fig. 3 illustrates a construction 40 showing a thermal transfer device 42 having a different configuration than the device 16 of Figs. 1 and 2. The device 42 of Fig. 3 is illustrated provided between a heat-generating component 44 and a heat dissipating component 46. Heat-generating component 44 can comprise, for example, an integrated circuit chip, and heat dissipating component 46 can comprise, for example, cooling fins or a heat sink.

[0009] Thermal transfer device 42 is in the shape of a pipe, and comprises a housing 48 surrounding a chamber 50. Housing 48 will typically comprise a thermally-conductive metallic material, such as, for example, copper or copper alloys. A wick 52

extends along the inside walls of chamber 50. Wick 52 can comprise, for example, a screen or other mesh, and in particular embodiments will comprise a copper screen. Chamber 50 is sealed relative to a surrounding atmosphere, and a working fluid is provided within the chamber. The working fluid evaporates from proximate component 44, and then condenses in a region proximate component 46. An arrow 53 is provided to show a vapor of the working fluid traveling upwardly within the pipe toward component 46, and another arrow 54 is provided to show the condensed fluid traveling along wick 52 to return to the region proximate heat-generating component 44. Thermal transfer device 42 is commonly referred to as a heat-pipe, while the thermal transfer device 16 is commonly referred to as a vapor chamber.

[0010] The desired characteristics described previously with reference to the thermal transfer device 16 of Figs. 1 and 2 are also applicable to the thermal transfer device 42 of Fig. 3. Specifically, it would be desired to develop devices having the configuration of device 42, but which are relatively lightweight compared to present constructions, and also which are preferably relatively low-cost to produce.

SUMMARY OF THE INVENTION

[0011] In one aspect, the invention encompasses a thermal transfer device. The device includes a housing which defines at least a portion of a chamber sealed from the atmosphere. The device also includes a working fluid contained within the chamber. The housing is formed of a composition which includes a polymer base matrix having a thermally conductive filler material dispersed therein.

[0012] In another aspect, the invention encompasses a thermal transfer device which includes a housing having a thermal conductivity of at least about 10 W/mK; with the housing comprising a polymer.

[0013] In yet another aspect, the invention encompasses a thermal transfer device which includes a wick comprising woven carbon fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

[0015] Fig. 1 is diagrammatic, side view of a prior art thermal transfer construction.

[0016] Fig. 2 is a diagrammatic, cross-sectional view of the Fig. 1 construction.

[0017] Fig. 3 is a diagrammatic, partial–sectional view of a second prior art thermal transfer construction.

[0018] Fig. 4 is a diagrammatic, cross-sectional view of a thermal transfer device encompassed by the present invention.

[0019] Fig. 5 is a diagrammatic, top view of a wick encompassed by methodology of the present invention.

[0020] Fig. 6 is a diagrammatic, cross-sectional view of a second embodiment thermal transfer device encompassed by the present invention.

[0021] Fig. 7 is a diagrammatic view of the Fig. 6 device along the line 7-7 of Fig. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The invention encompasses incorporation of new materials into thermal transfer devices, and also encompasses new thermal transfer device constructions. One aspect of the invention is described with reference to a thermal transfer device 100 in Fig. 4. Device 100 comprises a housing 102 which defines at least a portion of a chamber 104 (in the shown embodiment, the housing is defining an entirety of the shown portion of chamber 104). Chamber 104 is sealed from the atmosphere. In the shown embodiment, housing 102 comprises a first portion 106 joined to a second portion 108 at interface 110. Portions 106 and 108 preferably comprise a polymer base matrix having conductive filler material dispersed therein. The polymeric base matrix of portions 106 and 108 can comprise a thermoplastic, and can more specifically comprise one or more of polypropylene, liquid crystal polymer, and polyphenylene sulfide. The thermally conductive filler material can comprise, for example, metal powder or fibers,

and/or carbon powder or fibers. In a preferred embodiment, the thermally conductive filler material comprises carbon fibers provided within a polymer base matrix to a concentration of from about 10 volume percent to about 45 volume percent with a concentration of from about 30 volume percent to about 40 volume percent being more preferred. Preferably, the composition of polymer base matrix and conductive filler material utilized within housing 102 will have a through-plane thermal conductivity of at least about 10 watts/meter-kelvin (10 W/mK), and more preferably will have a through-plane thermal conductivity of at least 15 W/mK. In a particular embodiment, it is found that a housing comprising polypropylene with carbon fibers dispersed therein to a concentration of about 40 volume percent has a thermal conductivity of at least about 19 W/mK.

[0023] Housing 102 can comprise metal matrix composite materials in addition to, or alternatively to, the polymeric materials described above. Housing 102 can, in exemplary embodiments, comprise, consist of, or consist essentially of one or more of a copper/carbon composite, a copper/tungsten composite, a copper/silicon carbide composite, and an aluminum/silicon carbide composite. Additionally, housing 102 can comprise, consist of, or consist essentially of a material having a coefficient of thermal expansion of less than about 12ppm/°C; and in particular embodiments can comprise, consist of, or consist essentially of a material having a coefficient of thermal expansion of less than about 10ppm/°C.

[0024] Portions 106 and 108 of housing 102 can be formed by, for example, injection molding or other thermoforming methodologies. Portions 106 and 108 can be joined together by providing a suitable adhesive at interface 110 (with an exemplary adhesive being an epoxy). Alternatively, portions 106 and 108 can be joined by any of various welding technologies, including, for example, ultrasonic welding. In the shown embodiment, portions 106 and 108 are identical to one another, but it is to be understood that the invention encompasses other embodiments (not shown) wherein portions 106 and 108 are not identical to one another, either by differing in shape and/or

by differing in chemical composition relative to one another. Also, although the shown embodiment comprises a housing formed of two separate portions joined to one another, it is to be understood that the invention encompasses other embodiments wherein the housing comprises more than two separate portions joined together, and further encompasses a single unitary construction of the housing formed by, for example, injection molding of an entirety of the housing.

[0025] A wick 112 is provided within chamber 104, and a working fluid (not shown) is also provided within the chamber. In the shown embodiment, wick 112 extends along an inside wall of chamber 104 to split the chamber into a first region 114, the evaporator, and a second region 116, the condenser. Preferably, wick 112 will be permeable to the working fluid so that the working fluid can pass within wick 112 to regions where the working fluid has evaporated. Although wick 112 is shown extending along an inside wall of chamber 104, it is to be understood that other wick configurations can be utilized in methodology of the present invention, including, for example, a wick construction of the type described with reference to Fig. 2 as wick 24. However, a preferred wick construction of the present invention will be a material lining an inside evaporator wall of the chamber as shown. Additionally, although the shown wick extends along a bottom portion of the inside of the chamber, as well as along sidewalls of the inside of the chamber, it is to be understood that the invention encompasses other embodiments in which the wick extends in other configurations, such as, for example, embodiments in which the wick is along only one of the sidewalls, or embodiments in which the wick does not extend along either of the sidewalls, or embodiments in which the wick lines the top of the chamber.

[0026] Wick 112 will preferably have a large capillary pumping capacity to enable the wick to effectively pump working fluid in a direction opposite gravity. Such can be of particular importance in applications in which thermal transfer device 100 will be employed in portable consumer devices, as such devices are commonly rotated in numerous orientations relative to gravity during operation of the devices.

[0027] A preferred material for wick 112 is a woven carbon fiber fabric having the configuration illustrated in Fig, 5. The carbon fibers consist primarily of a first set of fibers 120 extending primarily along a first axis "Y", and a second set of carbon fibers 122 extending primarily along a second axis "X". The second axis "X" is substantially perpendicular to the first axis "Y". The second axis is referred to as being "substantially " perpendicular to the first axis as it is to be understood that there can be variations in the perpendicularity of the weave patterns of a fabric due to stretching and/or compression of the fabric. Further, the first and second sets of fibers are referred to as extending "primarily" along first and second axes, respectively, to indicate that the numerous bundled fibers of the first and second sets may comprise multiple orientations relative to the first and second axes, but that the general overall directions of the first and second sets of fibers are along the first and second axes, respectively. The weave pattern shown in Fig. 5 can be considered to be a so-called "plain weave" pattern. It is to be understood that such is an exemplary weave pattern, and that other weave patterns can be utilized in woven wicks of the present invention.

[0028] The carbon fibers utilized in wick 112 can be, for example, so-called pitch carbon fibers or so-called polyacrylonitrile (PAN) carbon fibers. The term "pitch carbon fibers" refers to carbon fibers which initially comprise pitch thereon, and which result from graphitization of the pitch; and the term "polyacrylonitrile carbon fibers" refers to carbon fibers which initially comprise acrylic fibers, and which result from graphitization of the acrylic. An exemplary pitch carbon fiber is available from BP Amoco as K-800X™ fiber, EWC-300X™ and EWC-600X™ fabric, and an exemplary PAN carbon fiber is available from BP Amoco as THORNEL™ T-300™ or T-650™. It is found that PAN carbon fibers can be more readily wet than pitch carbon fibers when utilizing water as a working fluid, and accordingly PAN carbon fibers can be preferred over pitch carbon fibers in particular applications.

[0029] An advantage of utilizing a woven fabric of carbon fibers, or other constructions of carbon fibers wherein the fibers extend in numerous directions, is that

the fibers can then wick working fluid effectively in multiple directions throughout chamber 104. In contrast, if the fibers are all aligned along a single primary direction, the working fluid will tend to be wicked only in that single direction, which can cause ineffective thermal transfer through device 100.

[0030] The wick construction of Fig. 5 can be a preferred wick construction, but it is to be understood that other wick constructions can be utilized in methodology of the present invention. For instance, another exemplary wick construction would comprise carbon fibers adhesively adhered to housing 102, such as can be accomplished by, for example, adhering GELVET™ along interior surfaces of housing 102 to line the cavity 104. Alternatively, an adhesive can be applied along inner surfaces of chamber 104, and carbon fibers can be flocked into the adhesive by, for example, utilizing an electric field to propel the fibers into the adhesive. Alternatively, a polymeric material of housing 102 can be softened by, for example, heating the housing material, and the fibers can be flocked directly into the housing material. In yet another alternative embodiment, carbon fiber filler material embedded in a housing polymeric matrix can be utilized as a wicking material by dissolving some of the polymeric matrix to expose the filler material.

[0031] An advantage of utilizing carbon fibers as a wicking material, relative to other wicking materials, such as, for example, copper particles or fibers, is that carbon fibers tend to have a lower thermal resistance than the conventional wick structures, which can allow more effective spreading of heat over an entire evaporative surface of device 100 than would otherwise occur with conventional wick materials. Alternative wick constructions that can be incorporated into devices of the present invention include metal particles or screens; polymeric materials having pores and/or grooves formed therein; and polymeric materials having additives therein or coatings thereon to improve wettability. Polymeric wick materials can, in particular embodiments, be coated with thermally conductive materials to improve thermal transfer to and through the wick materials.

[0032] In particular applications, a woven material wick of the type described with reference to Fig. 5 can be constructed, and then cut to appropriate size to be placed within housing 102 during formation of housing 102. The wick can either be placed between the portions 106 and 108 of housing 102 prior to adhering portions 106 and 108 to one another, or alternatively can be placed within an injection molding apparatus, and subsequently housing 102 can be formed around the wick.

[0033] The polymeric material of housing 102 is preferably non-permeable relative to a working fluid provided within chamber 104, as well as relative to atmospheric gases. Accordingly, a vacuum can be maintained within chamber 104, and the working fluid can also be retained within chamber 104. In embodiments in which the material of housing 102 is not sufficiently impermeable to one or both of the working fluid and atmospheric gases, a barrier layer can be provided over internal and/or external surfaces of housing 102. Such barrier layer can comprise, for example, MYLAR™, or metal. Depending on the material utilized for the barrier layer, the barrier layer can be formed by, for example, spraying, dipping, electrochemical deposition, and/or sputter-deposition.

[0034] It is to be understood that housing 102 can define some or all of the shown sealed chamber 104. Specifically, it is to be understood that a portion of the chamber seal can be formed of a material other than that utilized in housing 102. For instance, the housing 102 can define a chamber having a small hole therein. The small hole can be utilized for insertion of working fluid into the chamber and subsequent pulling of a vacuum within the chamber. The small hole can then be plugged with any suitable material to prevent loss of working fluid and/or vacuum from within the chamber. Also, it is to be understood that the invention encompasses embodiments wherein a thermally conductive polymeric material housing defines only a minor portion (i.e., less than half) of a sealed chamber, as well as embodiments in which the polymeric material housing defines most, substantially all (i.e, greater than 75% of the surface area of the chamber and less than 100% of the surface area of the chamber), or all of a sealed chamber. If

the thermally conductive polymeric material housing defines only a minor portion of a chamber, the remainder of the chamber can be formed of other materials, including, for example, non-thermally conductive polymeric materials (such as, for example, polymeric materials that do not have thermally conductive fibers dispersed therein) and metals. It can be preferable that at least some portion of a thermal transfer device surface have a coefficient of thermal expansion similar to that of a component being cooled by the thermal transfer device so that good physical contact can be maintained between the thermal transfer device and the component during changes in temperature.

[0035] It can be preferred that housing 102 have sufficient strength and rigidity to retain a desired shape while having a vacuum within chamber 104. If a material of housing 102 lacks sufficient strength and rigidity to maintain a desired shape, pillars (not shown) can be provided to extend across central regions of the chamber to provide additional structural support. Such pillars can extend around or through wick 112.

[0036] Referring to Fig. 6, another embodiment of the invention is illustrated as a construction 150. Construction 150 comprises a housing 152 surrounding a chamber 154. A wick 156 is shown lining at least some of the walls of chamber 154. Wick 156 can comprise, for example, the woven material wick 112 described above with reference to Fig. 5. Housing 152 comprises a unitary construction around wick 156, and further comprises a plurality of fins 158. Housing 152 can be formed of polymeric compositions identical to those described above with reference to housing 102 (Fig. 4) and can be injection-molded into the shown configuration. An advantage of molding cooling fins 158 from the polymer of housing 152, and incorporating cooling fins 158 and housing 152 into a unitary construction, is that such can eliminate an interface between a cooling fin material and a housing (such as, for example, the interface 15 described above with reference to Fig. 1). The interface between cooling fins and a thermal transfer device can impede thermal transfer between the device and the cooling fins, and accordingly incorporation of the cooling fins and housing 152 into a unitary structure can improve

the efficiency of thermal transfer within construction 150 relative to prior art constructions.

[0037] Although the structure of Fig. 6 shows cooling fins 158 in unitary construction with an entirety of housing 152, it is to be understood that the invention encompasses other embodiments wherein fins 158 are in unitary construction with only a portion of a housing. For instance, the invention encompasses an embodiment (not shown) wherein cooling fins 158 are incorporated in unitary construction with only one of the housing member portions 106 and 108 of the Fig. 4 construction.

[0038] Fig. 7 shows a diagrammatic view of the Fig. 6 device along the line 7-7. Such view illustrates wick 156 extending across an entirety of chamber 154 (Fig. 6). More specifically, housing 152 is illustrated comprising sidewalls 160, 162, 164 and 166, and wick 156 is illustrated extending from sidewall 160 to opposing sidewall 164, as well as from sidewall 162 to opposing sidewall 166. Wick 156 is illustrated comprising a simple planar construction, but it is to be understood that wick 156 can comprise a woven material of the type described with reference to Fig. 5 as material 112.

[0039] The thermal transfer devices of Figs. 4-7 are illustrated as vacuum chamber constructions, and would generally comprise rectangular shapes of the type shown in Fig. 7. However, it is to be understood that methodology of the present invention can be incorporated into thermal transfer devices having other shapes, such as, for example, heat pipes.

[0040] An advantage of devices of the present invention relative to the prior art devices such as that described with reference to Fig.1, is that devices of the present invention can be significantly more lightweight than conventional devices. For instance, a prior art thermal transfer device 16 of the type illustrated in Fig.1 would typically comprise a significant amount of copper or other metal, and would have a density per unit volume of at least about 3 grams/centimeter^3 (g/cm^3). In contrast a thermal transfer device of the type described with reference to Fig. 4 as device 100 comprises polymeric materials (such as plastics), and therefore can be much lighter than the prior art

constructions. For instance, an exemplary device of the present invention having the configuration illustrated in Fig. 4 will typically have a density per unit volume of less than about 1 g/cm^3, and can have a density per unit volume of, for example, about 0.86 g/cm^3.

[0041] In particular applications of the present invention, a thermal transfer device can be molded from polymeric materials present in an electrical device. For instance, it is common for electrical devices to comprise circuit boards for retaining and electrically connecting integrated chip devices. It is also common for such circuit boards to comprise polymeric materials. In particular applications of the present invention, the circuit board polymeric materials can be incorporated into thermal transfer device housings so that the thermal transfer devices are integral (and in exemplary applications, unitary) with the circuit board.

CLAIMS

1. A thermal transfer device, comprising

a housing, said housing being formed of a composition which includes a polymer base matrix having thermally conductive filler material dispersed therein, the housing defining at least a portion of a chamber, the chamber being sealed from the atmosphere; and

a working fluid contained within the chamber.

2. The thermal transfer device of claim 1 wherein the housing defines a majority of said chamber.

3. The thermal transfer device of claim 1 wherein the housing defines substantially all of said chamber.

4. The thermal transfer device of claim 1 wherein the housing defines all of said chamber except for a plug provided to seal an opening that extends through the housing to the chamber.

5. The thermal transfer device of claim 1 wherein the housing defines all of said chamber.

6. The thermal transfer device of claim 1 wherein the thermally conductive filler material comprises carbon fibers.

7. The thermal transfer device of claim 1 further comprising a wick within the chamber.

8. The thermal transfer device of claim 1 further comprising a wick within the chamber, the wick comprising carbon fibers.

9. The thermal transfer device of claim 1 further comprising a wick within the chamber, the wick comprising a fabric of carbon fibers.

10. The thermal transfer device of claim 1 wherein said composition has a thermal conductivity of at least about 10W/mK.

11. The thermal transfer device of claim 1 wherein the housing composition polymer base matrix comprises polypropylene, and wherein the thermally conductive filler material comprises carbon fibers.

12. The thermal transfer device of claim 1 wherein the housing composition polymer base matrix comprises polyphenylene sulfide, and wherein the thermally conductive filler material comprises carbon fibers.

13. The thermal transfer device of claim 1 wherein the housing composition polymer base matrix comprises liquid crystal polymer, and wherein the thermally conductive filler material comprises carbon fibers.

14. The thermal transfer device of claim 1 further comprising a plurality of cooling fins in unitary construction with at least a portion of the housing.

15. The thermal transfer device of claim 1 wherein the housing defines substantially all of the chamber, wherein an entirety of the housing comprises a unitary construction, and further comprising a plurality of cooling fins in unitary construction with the housing.

16. A thermal transfer device, comprising

a housing, said housing comprising a polymer and having a thermal conductivity of at least about 10W/mK, the housing defining at least a portion of chamber which is sealed from the atmosphere; and

a working fluid contained within the chamber.

17. The thermal transfer device of claim 16 wherein the housing defines a majority of said chamber.

18. The thermal transfer device of claim 16 wherein the housing defines at least substantially all of said chamber.

19. The thermal transfer device of claim 16 wherein the housing defines all of said chamber except for a plug provided to seal an opening that extends through the housing to the chamber.

20. The thermal transfer device of claim 16 further comprising a wick within the chamber.

21. The thermal transfer device of claim 16 further comprising a wick within the chamber, the wick comprising carbon fibers.

22. The thermal transfer device of claim 16 further comprising a wick within the chamber, the wick comprising woven carbon fibers.

23. The thermal transfer device of claim 16 wherein said material has a thermal conductivity of at least 15W/mK.

24. The thermal transfer device of claim 16 wherein the housing polymer comprises polypropylene.

25. The thermal transfer device of claim 16 wherein the housing polymer comprises polyphenylene sulfide.

26. The thermal transfer device of claim 16 wherein the housing polymer comprises liquid crystal polymer.

27. A thermal transfer device, comprising

a housing, the housing defining at least a portion of a chamber which is sealed from the atmosphere;

a working fluid contained within the chamber; and

a wick within the housing chamber, the wick comprising woven carbon fibers.

28. The thermal transfer device of claim 27 wherein the woven carbon fibers are pitch carbon fibers.

29. The thermal transfer device of claim 27 wherein the woven carbon fibers are polyacrylonitrile carbon fibers.

30. The thermal transfer device of claim 27 wherein the woven carbon fibers consist primarily of a first set of fibers extending primarily along a first axis, and a second set of carbon fibers extending primarily along a second axis which is substantially perpendicular to the first axis.

31. A thermal transfer device, comprising

a housing, the housing defining at least a portion of a chamber which is sealed from the atmosphere, the housing comprising a material having a coefficient of thermal expansion of less than about 12 ppm/°C;

a working fluid contained within the chamber; and

a wick within the housing chamber.

32. The thermal transfer device of claim 31 wherein an entirety of the housing is consists essentially of the material having a coefficient of thermal expansion of less than about 12 ppm/°C.

33. The thermal transfer device of claim 31 wherein the material comprises a coefficient of thermal expansion of less than about 10 ppm/°C.

34. The thermal transfer device of claim 31 wherein the housing comprises a metal matrix composite.

35. The thermal transfer device of claim 31 wherein the housing comprises a metal matrix composite; and wherein the metal matrix composite comprises a coefficient of thermal expansion of less than about 10 ppm/°C.

36. The thermal transfer device of claim 31 wherein the housing comprises a metal matrix composite; and wherein the metal matrix composite comprises copper and carbon.

37. The thermal transfer device of claim 31 wherein the housing comprises copper and tungsten.

38. The thermal transfer device of claim 31 wherein the housing comprises copper and silicon carbide.

39. The thermal transfer device of claim 31 wherein the housing comprises aluminum and silicon carbide.

40. The thermal transfer device of claim 31 wherein the wick comprises woven carbon fibers.

41. The thermal transfer device of claim 31 wherein the wick comprises woven carbon fibers, and wherein the carbon fibers are pitch carbon fibers.

42. The thermal transfer device of claim 31 wherein the wick comprises woven carbon fibers, and wherein the carbon fibers are polyacrylonitrile carbon fibers.

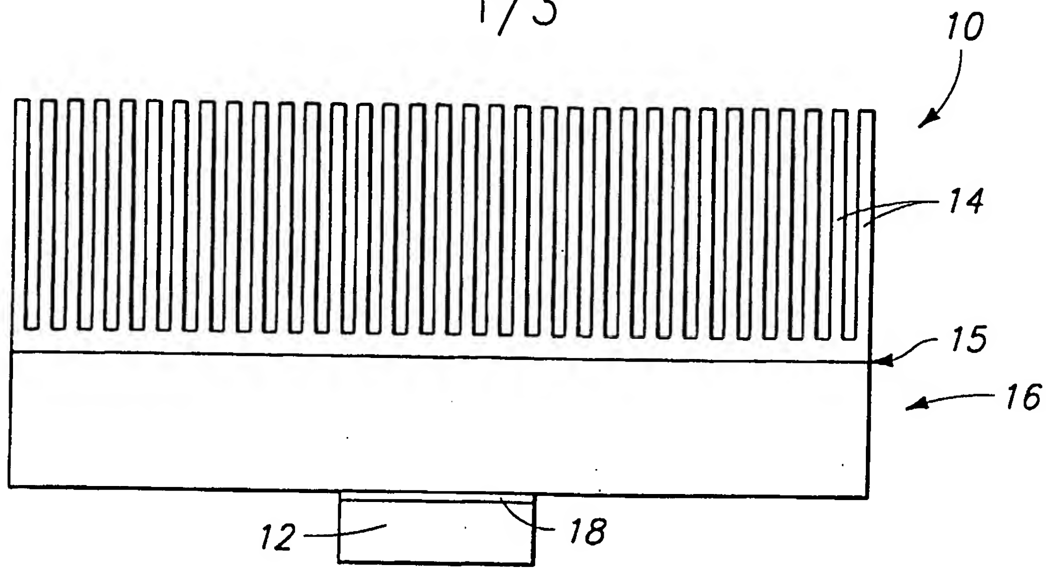

Fig 1
PRIOR ART

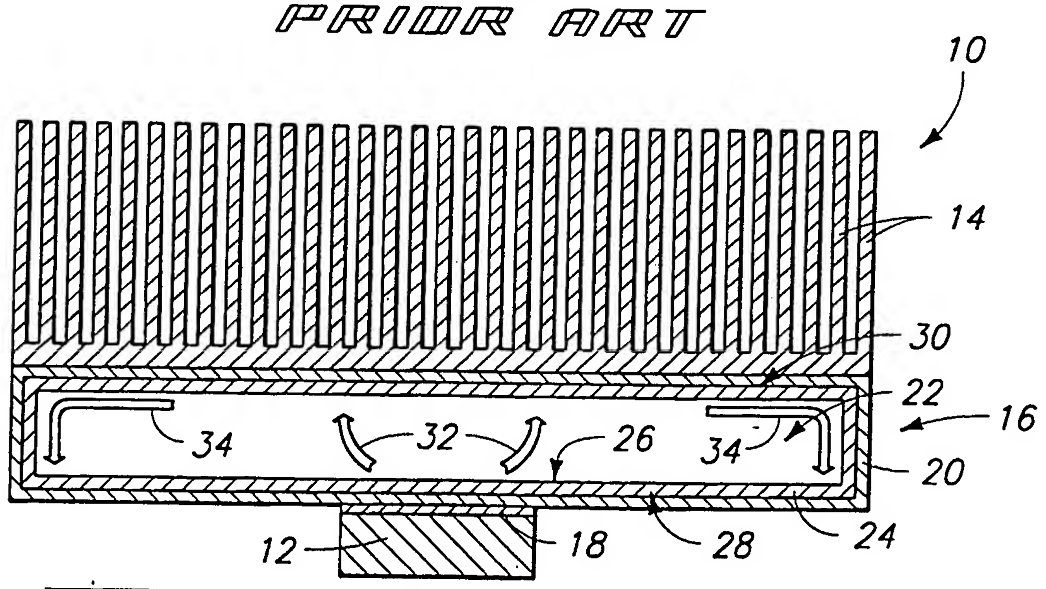

Fig 2
PRIOR ART

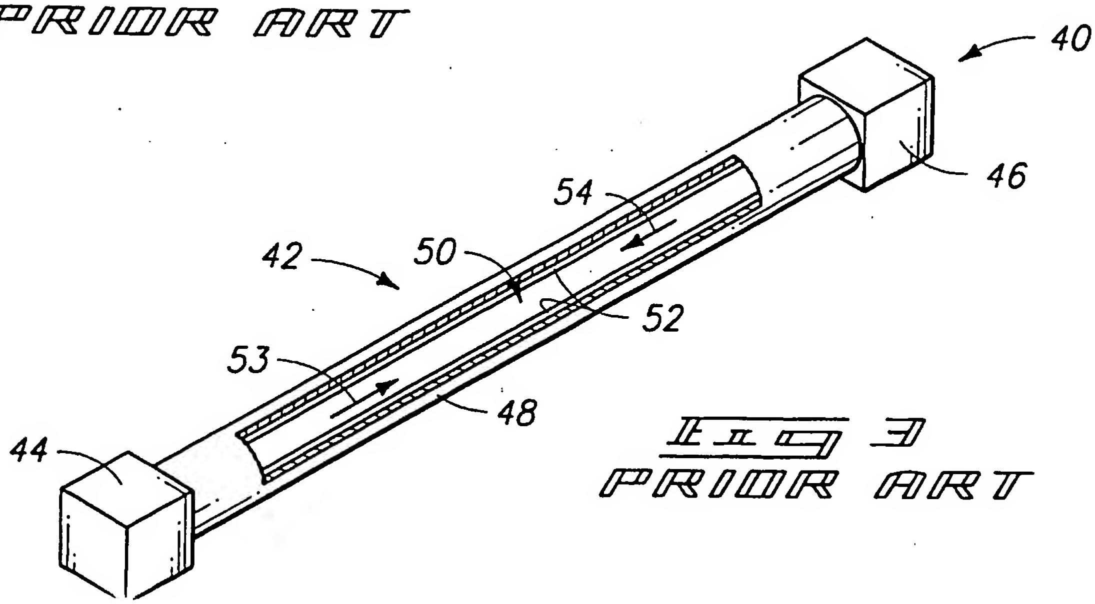

Fig 3
PRIOR ART

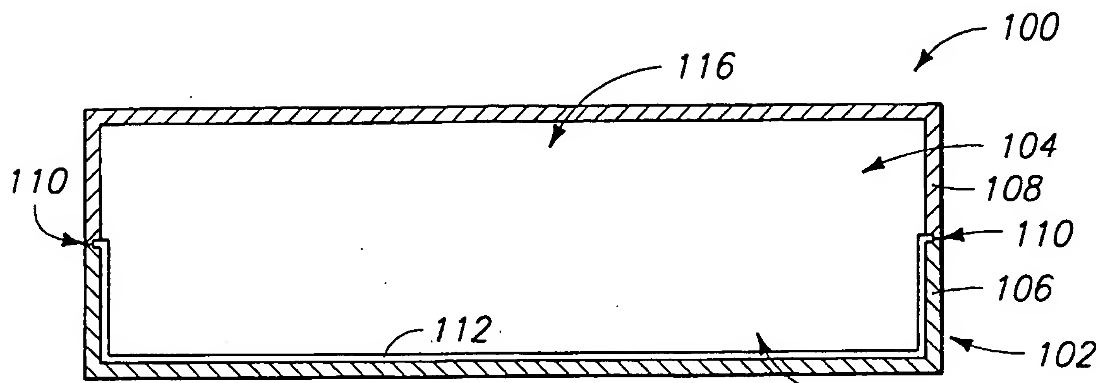

Fig 4.

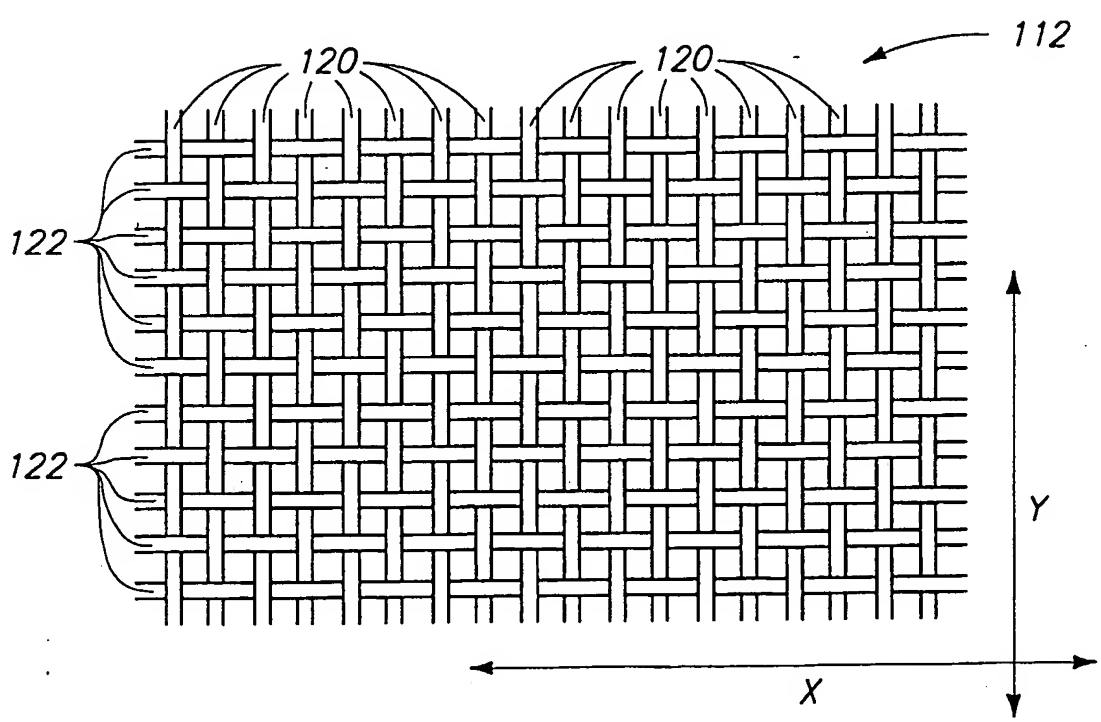

Fig 5

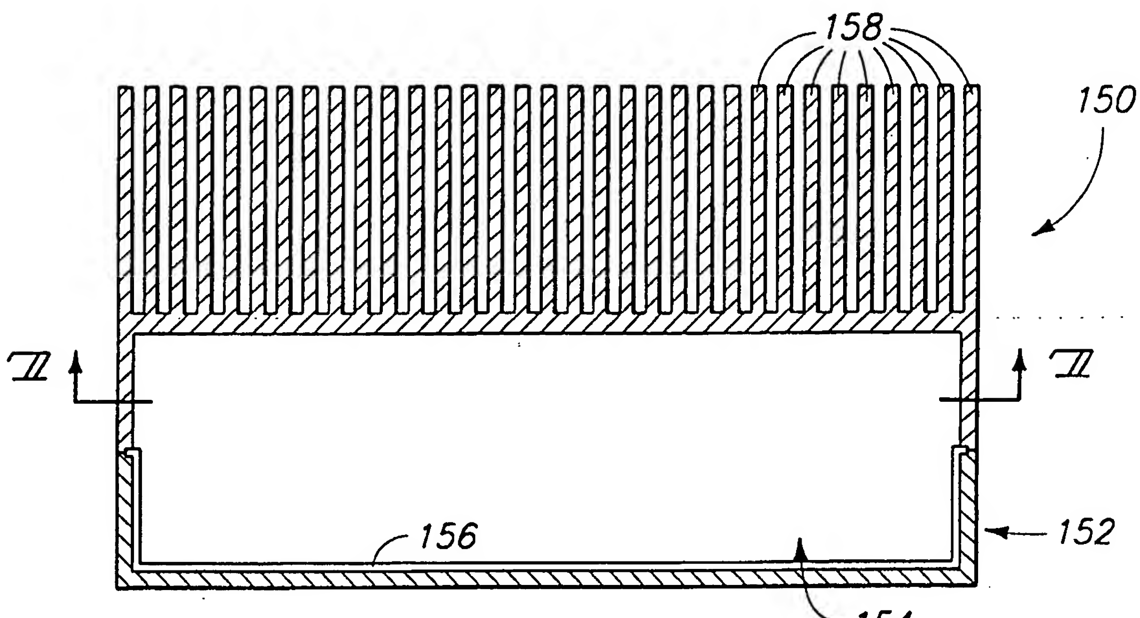

Fig 6

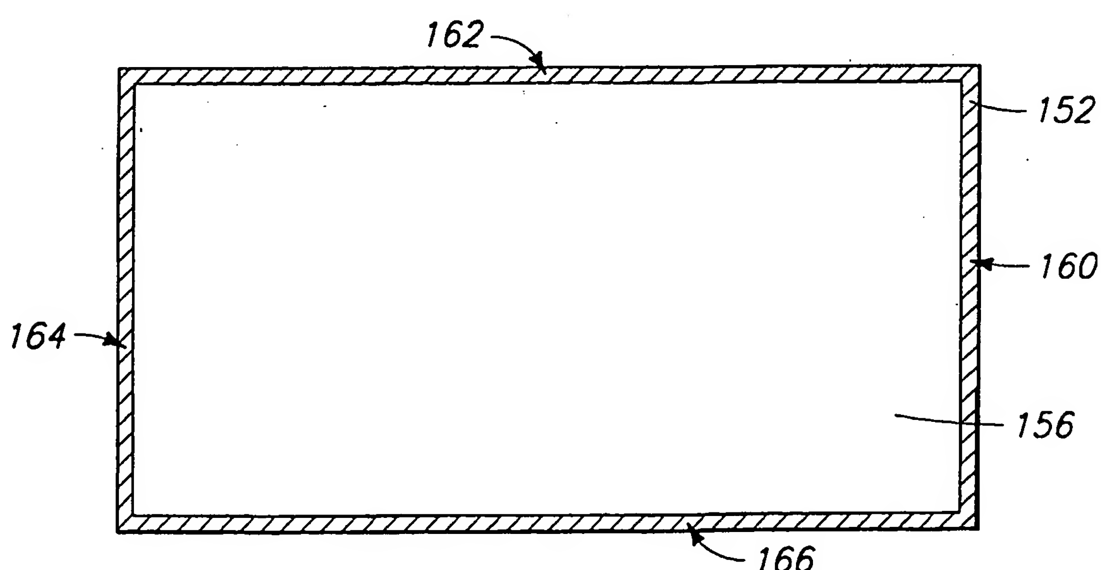

Fig 7

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(71) Applicant *(for all designated States except US)*: **HONEYWELL INTERNATIONAL INC.** [US/US]; 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **FLINT, James, Patrick** [US/US]; 4315 E. 28th Avenue, Spokane, WA 99223 (US). **DEAN, Nancy, F.** [US/US]; 1827 South Liberty Drive, Liberty Lake, WA 99019 (US).

(74) Agents: **LATWESEN, David, G.** et al.; Suite 1300, 601 West 1st Avenue, Spokane, WA 99201 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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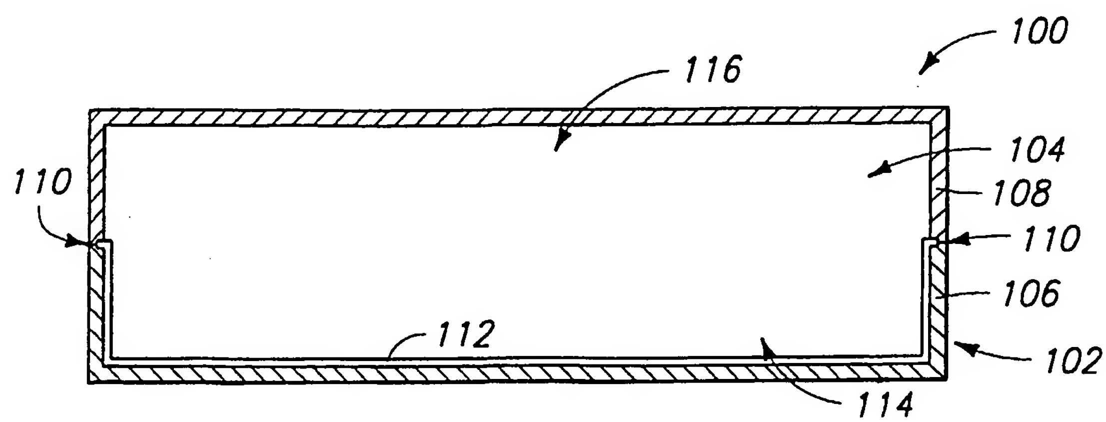
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: THERMAL TRANSFER DEVICES USING HEAT PIPES



(57) Abstract: The invention includes a thermal transfer device. The device includes a housing which defines at least part of chamber sealed from the atmosphere, and a working fluid contained within the chamber. The housing can be formed of a composition which includes a polymer base matrix having a thermally conductive filler material dispersed therein. The housing can have a thermal

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/25769

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L23/427 H01L23/373

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 99 26286 A (AMOCO CORP ;MILLER JAMES D (US); LEVESQUE KEVIN J (US)) 27 May 1999 (1999-05-27) abstract page 1, line 7 - line 10 page 4, line 22 -page 5, line 15 page 8, line 1 - line 3 page 9, line 26 -page 10, line 20 page 10, line 2 - line 24 page 17, line 17 - line 19 table 2 ---	1-6, 10-19, 23-26 7-9, 20-22, 28, 31-35, 40-42

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search	Date of mailing of the international search report
19 March 2003	28/03/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Favre, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/25769

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X Y A	WO 86 04982 A (FUJIKURA LTD) 28 August 1986 (1986-08-28) abstract; figures 1,2,7,8	27,29,30 7-9, 20-22, 28, 31-35, 40-42 36-39
A	US 5 076 352 A (ROSENFELD JOHN H ET AL) 31 December 1991 (1991-12-31) the whole document	1,7,16, 20,27,31
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 068 (E-716), 16 February 1989 (1989-02-16) & JP 63 254755 A (MITSUBISHI ELECTRIC CORP), 21 October 1988 (1988-10-21) abstract	14,15
A	EP 0 295 916 A (TAKEMOTO OIL & FAT CO LTD) 21 December 1988 (1988-12-21) page 4, line 37 - line 42	29,42

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-26

   A thermal transfer device comprising a housing, said housing being formed of a polymer base matrix having thermally conductive filler material dispersed therein and said housing having a thermal conductivity of at least 10W/mK, and the thermal transfer device further comprising a working fluid within a chamber.

2. Claims: 27-30

   A thermal transfer device comprising a housing, a working fluid contained within a chamber and a wick within the housing, said wick comprising woven carbon fibers.

3. Claims: 31-42

   A thermal transfer device comprising a housing, said housing comprising a material having a coefficient of thermal expansion of less than 12ppm/C, the thermal transfer device further comprising a working fluid contained within a chamber and a wick within the housing.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/25769

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9926286 A	27-05-1999	CA 2309630 A1	27-05-1999
		EP 1029352 A1	23-08-2000
		JP 2001523892 T	27-11-2001
		WO 9926286 A1	27-05-1999
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		EP 0295916 A2	21-12-1988
		US 4880881 A	14-11-1989

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International Bureau

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(71) Applicant *(for all designated States except US)*: HONEYWELL INTERNATIONAL INC. [US/US]; 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962 (US).

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(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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— *of inventorship (Rule 4.17(iv)) for US only*

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— *with amended claims*

(88) Date of publication of the international search report: 4 September 2003

Date of publication of the amended claims: 22 April 2004

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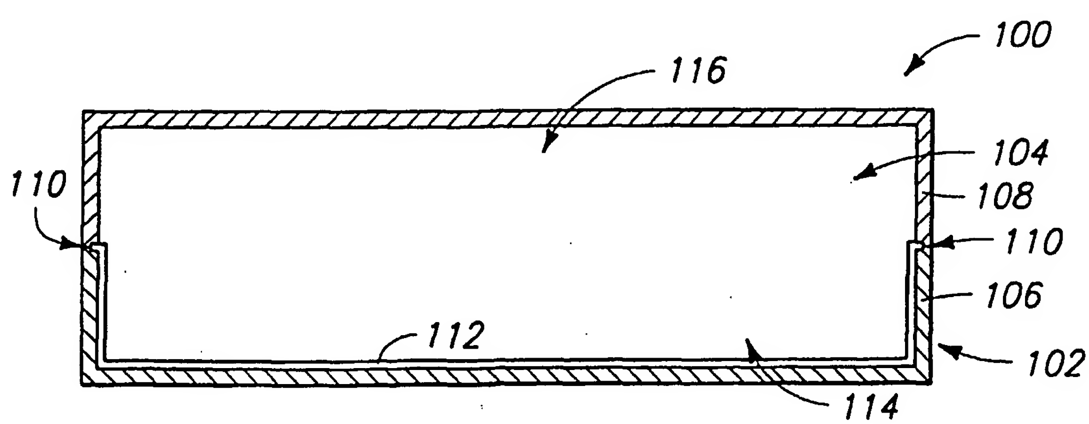

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WO 2003/017365 A3

AMENDED CLAIMS

[received by the International Bureau on 23 April 2003 (23.04.2003); original claims 1-42 replaced by amended claims 1-18 (4 pages)]

1. A thermal transfer device, comprising

a housing, said housing being formed of a composition which includes a polymer base matrix having thermally conductive filler material dispersed therein, the housing defining at least a portion of a chamber, the chamber being sealed from the atmosphere;

a wick within the chamber; and

a working fluid contained within the chamber.

2. The thermal transfer device of claim 1 wherein the wick comprises carbon fibers.

3. The thermal transfer device of claim 1 wherein the wick comprises a fabric of carbon fibers.

4. The thermal transfer device of claim 1 wherein said composition has a thermal conductivity of at least about 10W/mK.

5. The thermal transfer device of claim 1 wherein the housing composition polymer base matrix comprises polypropylene, and wherein the thermally conductive filler material comprises carbon fibers.

6. The thermal transfer device of claim 1 wherein the housing composition polymer base matrix comprises polyphenylene sulfide, and wherein the thermally conductive filler material comprises carbon fibers.

7. The thermal transfer device of claim 1 wherein the housing composition polymer base matrix comprises liquid crystal polymer, and wherein the thermally conductive filler material comprises carbon fibers.

8. The thermal transfer device of claim 1 further comprising a plurality of cooling fins in unitary construction with at least a portion of the housing.

9. The thermal transfer device of claim 1 wherein the housing defines substantially all of the chamber, wherein an entirety of the housing comprises a unitary construction, and further comprising a plurality of cooling fins in unitary construction with the housing.

10. A thermal transfer device, comprising

a housing, the housing defining at least a portion of a chamber which is sealed from the atmosphere, the housing comprising a metal matrix composite material having a coefficient of thermal expansion of less than about 12 ppm/°C;

a working fluid contained within the chamber; and

a wick within the housing chamber.

11. The thermal transfer device of claim 10 wherein the metal matrix composite comprises a coefficient of thermal expansion of less than about 10 ppm/°C.

12. The thermal transfer device of claim 10 wherein the metal matrix composite comprises copper and carbon.

13. The thermal transfer device of claim 10 wherein the metal matrix composite comprises copper and tungsten.

14. The thermal transfer device of claim 10 wherein the metal matrix composite comprises copper and silicon carbide.

15. The thermal transfer device of claim 10 wherein the metal matrix composite comprises aluminum and silicon carbide.

16. The thermal transfer device of claim 10 wherein the wick comprises woven carbon fibers.

17. The thermal transfer device of claim 10 wherein the wick comprises woven carbon fibers, and wherein the carbon fibers are pitch carbon fibers.

18. The thermal transfer device of claim 10 wherein the wick comprises woven carbon fibers, and wherein the carbon fibers are polyacrylonitrile carbon fibers.